UNIVERSITI TEKNOLOGI MARA

FABRICATION AND CHARACTERISATION OF NANOSTRUCTURED ZINC OXIDE THIN FILMS INCORPORATED WITH NANOROD ARRAYS-BASED SOLAR CELLS

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Thesis submitted in fulfillment
of the requirements for the degree of
Doctor of Philosophy

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CONFIRMATION BY PANEL OF EXAMINERS

I certify that a panel of examiners has met on 15th March 2017 to conduct the final examination of Mohd Firdaus Bin Malek on his Doctor of Philosophy thesis entitled "Fabrication and Characterisation of Nanostructured Zinc Oxide Thin Films Incorporated Nanorod Arrays-Based Solar Cells" in accordance with Universiti Teknologi MARA Act 1976 (Akta 173). The Panel of Examiners recommends that the student be awarded the relevant degree. The panel of Examiners was as follows:

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ABSTRACT

In this research, several types of solar cells have been successfully fabricated using zinc oxide-based nanoparticles (ZnO NPs) and ZnO-based nanorod arrays (ZnO NRAs). Both of ZnO NPs and ZnO NRAs were synthesised via novel dual sonication sol-gel immersion process. In this work, ZnO NRAs were grown on a seed layer by ultrasonic-assisted immersion technique while the seed layer, which consists of ZnO NPs were deposited by ultrasonic-assisted sol-gel dip-coating technique. The main points for this thesis are not only to successfully realise the controllable growth of ZnO NPs and ZnO NRAs but also investigate the structural, optical and electrical properties in detail by means of X-ray diffraction, field emission scanning electron microscopy, transmission electron microscope, energy dispersive X-ray spectroscopy, ultraviolet-visible-infrared spectrophotometry and two-probe current-voltage measurement system. There are several processing parameters such as dopant concentration, annealing temperature, growth time and various types of dopants which can be controlled were being optimised. The optimised growth parameters were applied to fabricate several solar cell devices which were dye sensitised solar cells (DSSCs), hybrid solar cells (HSCs), perovskite solar cells (PSCs) and inverted organic solar cells (IOSCs). The DSSCs with intrinsic ZnO NRAs immersed for 60 min demonstrated the highest conversion efficiency (η) of 3.268 %, a fill factor (*FF*) of 0.515, an open circuit voltage (V_{oc}) of 0.633 V and a short circuit current density (J_{sc}) of 10.032 mA/cm2 which due to higher dye loading in longer ZnO NRAs. On the other hand, the ZAO NRAs-based DSSCs which was immersed for 50 min prevailed preeminent performance for both immersion time and different dopant studies. The optimised of above-mentioned parameters leads to an efficiency (η) of 4.366 %, a fill factor (*FF*) of 0.482 an open circuit voltage (V_{oc}) of 0.592 V and a short circuit current density (J_{sc}) of 15.305 mA/cm^2. Besides, ZnO-based NRAs have been also successfully fabricated for both of HSCs and PSCs fabrication. For HSCs, MEH-PPV polymer has been essayed in HSC based on the various impurities within the ZnO NRAs and the best results have been obtained using ZAO NRAs (J_{sc} = 1.365 mA/cm^2, V_{oc} = 0.709 V, *FF* = 0.673 and η = 0.651 %). Apart from that, the PSCs with FTO/ZAO NPs/ZAO NRAs-50 min photoelectrode shows a better performance (J_{sc} = 8.028 mA/cm^2, V_{oc} = 0.534 V, *FF* = 0.517 and η = 2.215 %) compared to ZAO NRAs-30 min which might be due to higher infiltration of perovskite material. Finally, the ITO/ZnO/P3HT:PCBM/Au solar cells has been fabricated and the performance of the devide were successfully studied by varying the ZnO buffer layer thicknesses. The fabricated device of the IOSC yields the power conversion energy of 0.043 % using the optimum ZnO buffer layer thickness of 107.0 nm. This optimisation process not only provides the effective way to fabricate the solar cell devices, but also obtains some beneficial results in aspects of their properties, which builds theoretical and experimental foundation for much better understanding fundamental physics and broader applications of ZnO and related structures.

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